

VR 'SPACE OPERA': MIMETIC SPECTRALISM IN AN IMMERSIVE STARLIGHT AUDIFICATION SYSTEM

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November 11, 2016

Abstract

This paper describes a system designed as part of an interactive VR opera, which immerses a real-time composer and an audience (via a network) in the historical location of Göbeklitepe, in southern Turkey during an imaginary scenario set in the Pre-Pottery Neolithic period (8500-5500 BCE), viewed by some to be the earliest example of a temple, or observatory. In this scene music is generated, where the harmonic material is determined based on observations of light variation from pulsating stars, that would have theoretically been overhead on the 1st of October 8000 BC at 23:00 and animal calls based on the reliefs in the temple. Based on the observations of the stars V465 Per, HD 217860, 16 Lac, BG CVn and KIC 6382916, frequency collections were derived and applied to the generation of musical sound and notation sequences within a custom VR environment using a novel method incorporating spectralist techniques. Parameters controlling this resynthesis can be manipulated by the performer using a Leap Motion controller and Oculus Rift HMD, yielding both sonic and visual results in the environment. The final opera is to be viewed via Google Cardboard and delivered over the Internet. This entire process aims to pose questions about real-time composition through time distortion and invoke a sense of wonder and meaningfulness through a ritualistic experience.

1 Introduction

The system we have developed forms the basis for the forthcoming opera *Motherease*. It immerses a real-time composer and an audience (via a network) in the historical location of Göbeklitepe, in southern Turkey during an imaginary scenario set in the Pre-Pottery Neolithic period (8500-5500 BCE). A description of the networking features of this package is beyond the scope of this paper, instead we will concentrate on the virtual staging, sound resynthesis and sonification aspects of our system.

Rather surprisingly so, FFT analysis, which is so commonly employed in the composition of spectral music, originates from a formula designed for rapidly calculating the elliptical orbits of planetary bodies. This early version of the DFT is a development attributed to Alexis- Claude Clairaut in 1754 [1] but one could look even further back to ancient Babylonian mathematics if the term 'spectral analysis', which is often used to describe the method by which spectralist composers derive musical material for their compositions, and is sometimes a stand in for 'harmonic analysis' [2]. Of course since the

term harmonic analysis already connoted something entirely different amongst musicologists by the time the French Spectralist tradition began in the 1970's, this linguistic evolution makes sense, despite being a slightly confusing side effect both of the difficulties of categorization and the interdisciplinary nature of Spectralism. Mostly the term spectral analysis is used in an even more narrow sense when speaking in the context of spectral music however, to refer to DFT or FFT analysis of audio signals containing content from within the audible frequency range (20 Hz and 20.000 Hz) to yield a collection of frequencies (pitches) and their amplitude (dynamic) variance over time for a composition. Indeed the stipulation that spectral analysis produces musical results is a creative leap of faith that supports the co-option of this process into the composer's repertoire of compositional techniques, and for good reason. Why shouldn't one look to mathematics to help build a stronger understanding of music via recognition of the structural underpinnings of sound, the very concrete from which this art form emerges?

Yet at the same time why stop at the analysis of sound to produce frequency collections from which to derive new harmonies and timbres? FFT analysis is a tried and tested tool for modelling a musical representation of a subject, using the program *Macaque*¹ in combination with a SDIF file for example, one can easily track the movement of a sound spectrum over time such as was done by Gérard Grisey through a similar method for his seminal work *Partiels* [3], whose methods we will focus on here. If FFT analysis translates its usefulness so well from the realm of the cosmos into such a diverse array of phenomena such as audio signal processing, medical imaging, image processing, pattern recognition, computational chemistry, error correcting codes, and spectral methods for PDEs [4], it is perhaps no more worthy a candidate for the source of frequency based musical inspiration than any other similar method of observing the natural world's many oscillations.

So is the practice of using other algorithmic methods to interpret natural phenomena any less valid or useful to the composer? The process of sonification,

or audification as it is more commonly known to astronomers, is fairly widespread due to the pragmatic consequence, of speeding up time-consuming manual data analysis. When approaching spectral music composition in real-time scenarios as is the case in the project presented in this paper, the speed at which abstractions of these forms can be realised as sound is paramount to their success as music of course, but perhaps the most important aspect is the representation of the entity in music, an entity which itself does not transmit any sound through the great vacuum of space, over distances of multiple light years. It is therefore fairly reasonable to assume that the usefulness of spectral compositional methods remains, even if FFT analysis or some tonal system built around the 'natural harmonic series' is removed from this linear process, and replaced with another algorithm designed to derive a similar kind of 'tonal reservoir'[2] for our purposes.

The use of starlight audification to create musical textures has precedent [5] but has so far not been incorporated into a real-time spectral composition system. Of primary relevance to this particular research project is the clear, discernable embodiment of extra-musical objects inside of a musical context known as 'Mimetic Spectralism'[6]. It may therefore prove no more relevant to us to base a composition on sound itself, once it is abstracted to the point of mathematical analysis, than on any other method of analysis of a physical phenomenon, which we consider a form of embodiment. The apotheosis of sound as a kind of 'living object with a birth, lifetime and death'[11] as Grisey put it, is not the focus here. Certainly in the light of careful review by a skilled composer (or just one with the right software tools), any collection of frequencies can be stretched through a wide array of aesthetic extremes, as the practice of spectralism is after all an impressionistic exercise [7].

2 Spectralism and Belief

It has been observed that the use of FFT analysis in music composition may imply an extra-musical dimension to the piece concerned [8]. The assertion that what the composer produces using spectral techniques is music often comes along with cer-

¹<http://georghajdu.de/6-2/macaque/>

tain presumptions and philosophies about the nature of sound and music perception. Inevitably, this extra-musical motivation pushes this music into the territory of referential expressionism [9]. One tendency among proponents of spectralism is to justify their use of spectral technique by referencing its links to the sciences. Many proponents of the movement claim that forms extracted from within sonic events represent a natural and fundamental order of music as evidenced by the micro-structure of sound. Despite the scientific origins of the techniques used in spectral composition, they are of course not by themselves scientific proofs of 'musical truths'. Instead, it has instead been suggested that when 'new art' is generated from the analysis of 'natural' objects, this indicates naturalism as the philosophical basis for the art piece concerned [8]. Extra-musical representation in spectral music is not always the intention of the composer, but sometimes it is unavoidable. Gérard Grisey exhibits a kind of devotional respect for sound that is almost animistic. Grisey proposed that spectral music reminds the listener that sound is in fact living. "Spectralism is not a system. It's not a system like serial music or even tonal music. It's an attitude. It considers sounds, not as dead objects that you can easily and arbitrarily permute in all directions, but as being like living objects with a birth, lifetime and death." (Grisey, 1996) With this anthropomorphic approach to sound Grisey displays this reverence towards the source of his compositions and his muse, sound itself. In the same interview he mentions that while his music represents a 'state of sound' it is simultaneously a discourse: I would tend to divide music very roughly into two categories. One is music that involves declamation, rhetoric, language. A music of discourse... The second is music which is more a state of sound than a discourse... And I belong to that also. I would put myself in this group. Maybe I am both, I don't know. But I never think of music in terms of declamation and rhetoric and language. (Grisey, 1996) With this impetus we created a system that explores animism and discourse through re-synthesis in a ritualistic setting. We set out to create a music of discourse, which embodies starlight and animal calls in the music, which is generated via commonly used spectralist techniques such as Orchestral resynthesis

and spectra as reservoir among others. Here we will detail our approach to Mimetic Spectralism.

3 Theoretical Framework for Starlight Audification

Pulsating stars simply expand and shrink within their radius periodically, because of the interior mechanisms related with their opacity. The observation of this type of star gives us valuable information about the inner parts of these stars. The increased opacity inside a pulsating star helps to produce heat energy that forces the star to expand. This expansion causes a decrement in the opacity, which results in a shrinkage. The recurrence of this cycle makes the pulsating stars a fascinating candidate for astronomical observation. The observations of the light variation from a pulsating star results in a wave shaped variation of light over time (Fig. 1).

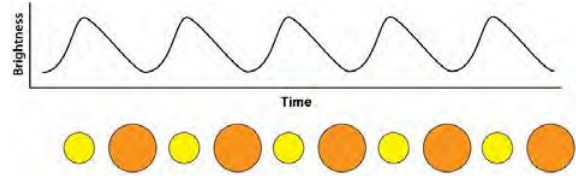


Figure 1: The light curve of a pulsating star in comparison with its radius (Credit: <http://www.spaceexploratorium.com>)

In the case of multiperiodic pulsating stars this wave shape takes a very complicated form and it can only be decomposed to several sine like variations with certain frequencies (f), amplitudes (A) and phase shifts (ϕ) by applying frequency analysis. The similarity between observed -wave shaped- light from pulsating stars and a superposed simple sound wave is used in converting the stellar oscillations to audible sounds in our study.

In order to audify the detected oscillation frequencies of a pulsating star, we used the method described by [5]. The author defined three dimensionless parameters based on the pulsation characteristic of a star: the first parameter is Relative Frequency, $f' = \frac{f_i}{f_{min}}$, which is the ratio of a given frequency to

Table 1: The parameters for Sct type pulsating star V465 Per. The pulsation parameters f , A , ϕ are taken from [10]. Note that $f_{min} = 13.721$ $A_{max} = 3.5$ mmag and $\phi_{min} = 0.14$. The frequency value of C_4 , 261.630 Hz, is taken from [11].

f (c/d)	A(mmag)	ϕ	f'	L	p	$f' \times C_4$ (Hz)
14.040	3.5	-0.14	1.023	1.000	0.00	267.647
17.208	2.3	2.05	1.254	0.657	2.19	328.084
33.259	1.7	1.93	2.424	0.488	2.07	634.191
13.721	1.1	3.55	1.000	0.314	3.69	261.630

the minimum frequency in detected group. The second parameter is the Loudness Parameter, $L = \frac{A_i}{A_{max}}$, which is the ratio of the amplitude value for a given frequency to the maximum amplitude value among the frequency group. The last parameter, $p = \frac{\phi_i}{\phi_{min}}$, is the Starting Parameter of the signal. It gives us the difference between the phase shift of a wave and the minimum phase shift value of the group. A light variation profile obtained from the star can be converted to a sound wave by moving the minimum frequency value to a desired frequency in the audible range and by keeping the relation between frequencies, amplitudes and phase shifts. We used five pulsating stars (V465 Per [10], HD 217860 [14], 16 Lac [15], BG CVn [16], KIC 6382916 [17]) to produce sounds from the analysis of their observational data. As an example, we give the pulsation parameters f , A , ϕ , related dimensionless parameters f' , L , p and the result of the multiplication with C_4 for one of our stars, V465 Per Table 1.

For the generation of sound waves from these dimensionless parameters AUDACITY was used. The calculated relative frequencies for a star was multiplied by the frequency value of fourth octave C (see Table 1). The loudness and the starting times are also arranged according to appropriate values. For instance, when converting one observed frequency, say 14.040 d-1, of the star V465 Per to audible range we follow these steps: (i) we multiplied the dimensionless relative frequency by the frequency value of C_4 , then we entered the new frequency value (i.e. 267.647 Hz) as the frequency of a sound wave.(ii) the Loudness parameter (1.000) was entered directly to the program as the normalized amplitude value. (iii) The starting time parameter (0.00) was set as the

starting time of the sound in AUDACITY. Since we have 4 observed frequencies for this star we repeated the process for each of the 4 frequencies listed in Table 1, therefore, we obtained 4 different superposed sound waves characterised by the calculated parameters given in the table. Finally these sound waves were recorded to a digital sound file. We hope to expand on this method with orchestral resynthesis once our system as expanded beyond the early prototyping stages. Below we detail an initial implementation utilizing the audio files we created as described here.

4 Opera Realisation

The bulk of the project is realized using the Unity-3d engine and standard assets, with some additions from the Unity app store, most notably the Leap Motion Project Orion Beta, which vastly improves the quality of tracking possible with the Leap Motion camera in comparison the previous assets. The standard character controller included with the Oculus Rift assets was not appropriate due to our intention to port the system to Google Cardboard², after the initial development done with the Oculus Rift DK2³ and Leap Motion⁴ camera. Initially there were some problems stemming from the loss of Oculus Rift DK2 Mac OS X support, these had to be overcome by porting the project to a Windows 10 development environment. An important element is the *InstantVR Free* asset from *Passer VR*⁵, which made it possible to port between different VR setups and platforms relatively

²<https://www.google.com/get/cardboard/>

³<https://www.oculus.com/en-us/dk2/>

⁴<https://www.leapmotion.com/>

⁵<http://serrarens.nl/passervr/>

easy.

Set design was made easier through importing freely available photo-scanned models of historical artifacts or with standard assets as well, saving time on 3d modelling (Fig. 4.). The majority of the set is actually a 360-degree photograph taken in one of the temples; this was processed into a skybox using the *Panorama to Skybox* asset after being edited into a night-like scene in Photoshop. Some stitching lines are still visible, but they are mostly obscured with particle systems ranging from fog to fire and light. The actual characters in the scene are animated by pre-recorded animations, which are triggered based on the selections made by the real-time composer.

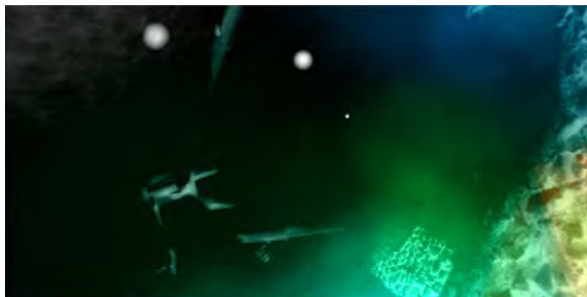


Figure 2: The stage from the real-time composers perspective, 3 stars at different levels of luminosity, in the foreground a fog particle system.

5 The User Interface

The real-time composer controls the playback of material by selecting single stars with their hand movements (pinch gesture). Once a particular star is selected, its partials can be used to manipulate the audio of animal calls related to the pictograms featured on reliefs at the Göbeklitepe site. The user is able to manipulate these sound files from within the VR environment through the Leap Motion controller and the Unity audio SDK. Visually the stars themselves increase and decrease in luminosity in accordance with the relative loudness of each group (Fig. 2). For example, the real-time composer orients their hand along the axis of a particular star and their finger positions affect the amplitude of the



Figure 3: A user manipulates the interface with the HMD mounted Leap Motion Controller.

sine waves related to that star. In the case of V465, the user controls the volumes of 4 sine waves with the degree of extension of their pinky, ring, middle and index fingers (Fig 3). Using gesture recognition the user can also open a HUD, populated by some of the pictograms found throughout the Göbeklitepe site. Selecting one of these pictograms loads a sound file related to the particular animal represented i.e. bison, wild boar, crocodile etc. These sounds can be used with the *SpectraScore*⁶ Max/MSP abstraction to generate spectral music, including scores. Various audio effects allow the user to modify the source sounds in realtime with their movements.

6 Conclusion

As this project is in its early stages there is much room for improvement in terms of the interface and software in general. Mainly though, the level of latency experienced between the real-time composers actions and sounding results needs to be improved to create a smoother 'soundbonding' [12] effect. In order to achieve this, a new system may have to be created relying on playback of samples from the audiences HMDs to reduce network strain. This would hopefully be done with samples of acoustic instruments such as is currently done with SpectraScore via MIDI or OSC. Spatialisation would then become

⁶<https://github.com/benedictcarey/SpectraScorebeta-0.4>

a further layer of complexity, due to the strain of performing DSP in a smartphone headset.

All in all our success at bringing together techniques of spectral music composition methods and starlight audification points at the relative ease through which new algorithms can be imported into existing algorithmic music composition frameworks. Since this project was realised in VR, the exploratory nature of real-time composition was brought into focus through the use of 'source objects', that is, 'material objects'(Culverwell⁷) that have been analysed and re-represented in a musical form as spectral morphemes (representing the physical forms from which they were derived). This referential expressionist form of Spectralism creates new possibilities for a kind of figurative interaction between 'Gestalten' that are otherwise incomparable. Thanks also to an extensive array of virtualised real-world objects available in online collections and stores (i.e Sketchfab, Turbosquid, Unity Asset Store), and the ever increasing documentation surround the mapping of the sky above the Earth, the possibilities for sonification with the techniques described here will continue to grow and increase in relevance for proponents of the *Gesamtkunstwerk*.



Figure 4: A user manipulates the interface with the HMD mounted Leap Motion Controller.

References

- [1] Zayed, Ahmed I., 1996, Handbook of function and generalized function transformations. CRC press,
- [2] Fineberg, J. N., 1999, 'Sculpting sound: an introduction to the spectral movement - its ideas, techniques and music'. PhD thesis, Columbia University.
- [3] Féron, F.-X., 2010, "Gérard Grisey: première section de Partiels (1975)." Genesis". Manuscrit-RechercheInvention 31: 77-97.
- [4] The FFT - An algorithm the whole family can use, Computing in Science & Engineering, January/February 2000, 2, Number 1, pp. 60-64.
- [5] Ulaş, B., 2015, arXiv:1507.0730.
- [6] Teodorescu-Ciocanea, L., 2003, Timbre versus spectralism. Contemporary Music Review, 22(1-2), 87-104.
- [7] Malherbe, C., Fineberg, J., & Hayward, B., 2000, Seeing Light as Color; Hearing Sound as Timbre. Contemporary Music Review, 19(3), 15-27.
- [8] Moscovich, V., 1997, "French spectral music: An introduction." Tempo : 21-27.
- [9] Meyer, L. B., 2008, Emotion and meaning in music, University of Chicago Press.
- [10] Kim, S.-L. and Lee, S.-W., 1998, Astronomy and Astrophysics Supplement, v.128, p.111-116.
- [11] Suits, B. H., 1998, <http://www.phy.mtu.edu/suits/notefreqs.html>
- [12] Smalley, D., 1997, "Spectromorphology: explaining sound-shapes." Organised sound 2(02): 107-126.
- [13] Bundler, D., 1996, "Interview with Gerard Grisey." 20th Century Music.
- [14] Frémat, Y. et al., 2007, Astronomy & Astrophysics, 471, 675.
- [15] Chapellier, E. et al., 1995, Astronomy & Astrophysics, 304, 406.

⁷<http://www.oxforddictionaries.com/definition/english/material-object>

- [16] Paparó, M. et al., 2013, Monthly Notices of the Royal Astronomical Society , 432, 598.
- [17] Ulusoy, C. et al., 2013, Monthly Notices of the Royal Astronomical Society, 433, 394.